



Marine Mammal Detection Final Report

Call-Up Against the Noise Monitoring Standing Offer

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Defence R&D Canada – Atlantic

Contract Report
DRDC Atlantic CR 2005-271
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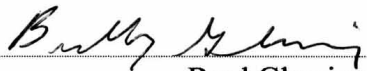
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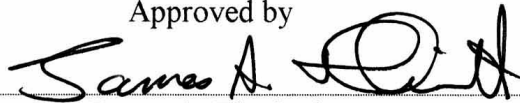
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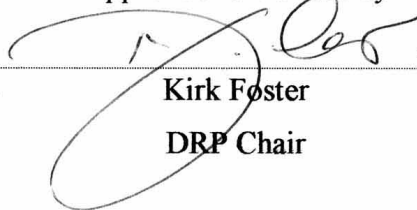
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Abstract

This report documents the work done to prototype a marine mammal detection system. The resulting system will support environmental mitigation measures prior to, and during, active sonar trials and exercises. A working application was delivered at the end of the call-up that allows a user to configure and run detection processing, with live updates provided, or to post-analyze data from a previous detection run. Once selected, an image of the detection and the corresponding detection log entries are presented to the user. The user can also listen to the detection and bring up a time series plot of the raw data. A cursor can be used to measure times and frequencies on the detection image. This system was used to process 30 minutes of Right whale data collected using sonobuoys. Desharnais collected this data set in the Bay of Fundy during the summer of 1999. This data set included dead channels, considerable radio frequency (RF) interference and a digital data channel. Fifty-seven valid detections were made while the sixteen false alarms that did occur were easily classified and rejected. No analysis of missed contact was made. After a quick look at the data, it took an acoustic operator less than a second to distinguish a valid call from a false alarm as he scrolled through the results. Aural listening helped to quickly distinguish valid vs. invalid contacts. There is still considerable room for improvement in the automatic classification and graphical user interface (GUI) layout but, as a prototype, it demonstrates that good detections can be made and classified using a system such as this. The processing stream is based primarily on existing signal processing library (SPLIB) and sonar library (SONLIB) modules developed under previous call-ups. The GUI was based on existing QT-based widgets developed under the Omni Passive Display (OPD) call-up.

Résumé

Le présent rapport fait état des travaux effectués sur un système prototype de détection de mammifères marins. La version finale du système viendra appuyer les mesures de protection environnementale avant et pendant les essais et exercices faisant appel au sonar actif. À la fin de la commande directe, l'entrepreneur a livré une application opérationnelle qui permet à l'utilisateur de configurer et d'exécuter le traitement des données de détection, avec des mises à jour en temps réel, ou d'effectuer une analyse postérieure des données d'un essai de détection antérieur. Une fois sélectionnée, une image de la détection et les entrées correspondantes dans le journal de détection sont présentées à l'utilisateur. L'utilisateur peut également écouter le signal sonore de la détection et appeler à l'écran un graphique chronologique des données brutes. Un curseur peut être utilisé pour mesurer le temps et les fréquences de l'image de détection. Ce système a été utilisé pour traiter 30 minutes de données de détection de baleines noires collectées au moyen de bouées acoustiques. Desharnais a collecté cet ensemble de données dans la baie de Fundy au cours de l'été 1999. Cet ensemble de données comprenait des canaux inactifs, du brouillage radiofréquence (RF) considérable et un canal de données numériques. Cinquante-sept détections valides ont

été effectuées, tandis que les seize fausses alertes qui se sont produites ont été faciles à classer et à rejeter. Aucune analyse de contacts manqués n'a été effectuée. Après un survol rapide des données, un opérateur de détecteurs acoustiques a mis moins d'une seconde à distinguer entre un contact valide et une fausse alerte pendant qu'il faisait défiler les résultats. L'ouïe a aidé à distinguer rapidement entre les contacts valides et non valides. Il y a encore beaucoup de chemin à faire à l'égard de la classification automatique et de la disposition de l'interface graphique (GUI), mais le prototype a montré que de bonnes détections peuvent être effectuées et classifiées au moyen d'un système de ce genre. Le flux de traitement est essentiellement fondé sur les modules existants de bibliothèque de traitement de signaux (SPLIB) et de bibliothèque sonar (SONLIB) développés dans le cadre de commandes directes antérieures. L'interface GUI était basée sur des objets fenêtres axés sur QuickTime développés dans le cadre de la commande directe visant l'affichage Omni passif (OPD).

Executive summary

Background

DRDC Atlantic has an ongoing research program that requires the transmission of acoustic energy in an undersea environment. Though the transmissions are generally at a relatively low level, every effort must be made to mitigate the potential for impact on marine life.

Recent increased awareness regarding the potential for adverse impact on marine fauna from anthropogenic noise has resulted in further research being undertaken to study the impact mechanisms and possible mitigation measures. Future impact mitigation measures may include the development of detection and classification capabilities for marine mammal vocalizations. The ocean environment tends to be noisy, so that the detection of noise itself is inadequate for alerting researchers of the presence of marine mammals. The “noise” must be classified as to its origin, e.g. has it been generated by a marine mammal. The objective of this contract was to develop a prototype acoustic auto-alert system for use on DRDC Atlantic sea trials.

Results

A working application was delivered at the end of the contract that allows a user to configure and run detection processing, with live updates provided, or to post-analyze data from a previous detection run. Once selected, an image of the detection and the corresponding detection log entries are presented to the user. The user can also listen to the detection and bring up a time series plot of the raw data. A cursor can be used to measure times and frequencies on the detection image. This system was used to successfully process 30 minutes of sonobuoys data containing Northern Right whale vocalizations.

Significance

There is still considerable room for improvement in the automatic classification and graphical user interface (GUI) layout but, as a prototype, it demonstrates that detections can be made and classified using a system such as this.

Future Plans

The initial testing of the system has been very positive. However, more testing is required with “noisy” data. Beyond more testing, the addition of classifier algorithms and analogue “click” detectors are the obvious next steps.

Glessing, B. and J. Hood 2005. Marine Mammal Detection Final Report. DRDC Atlantic CR 2005-271. Defence R&D Canada – Atlantic.

Sommaire

Contexte

RDDC Atlantique mène un programme de recherche permanent qui exige la transmission d'énergie acoustique dans un environnement sous-marin. Bien que les transmissions soient généralement d'un niveau relativement faible, il faut tout faire pour atténuer l'incidence potentielle sur la biosphère marine.

La conscience accrue depuis peu quant à l'effet nuisible potentiel du bruit anthropique sur la faune marine a donné lieu à des recherches approfondies sur les mécanismes en cause et les mesures d'atténuation possibles. Les mesures futures d'atténuation de l'incidence peuvent comprendre le développement des capacités de détection et de classification des vocalisations des mammifères marins. L'environnement océanique tend à être bruyant, de sorte que la détection du bruit en soi ne suffit pas pour alerter les chercheurs à la présence de mammifères marins. Le « bruit » doit être classifié selon son origine, c.-à-d. qu'il faut déterminer s'il a été produit par un mammifère marin. Le contrat en cause avait pour objectif de développer un système prototype d'alerte acoustique automatique pour utilisation pendant les essais en mer de RDDC Atlantique.

Résultats

À la fin du contrat, l'entrepreneur a livré une application opérationnelle qui permet à l'utilisateur de configurer et d'exécuter le traitement des données de détection, avec des mises à jour en temps réel, ou d'effectuer une analyse postérieure des données d'un essai de détection antérieur. Une fois sélectionnée, une image de la détection et les entrées correspondantes dans le journal de détection sont présentées à l'utilisateur. L'utilisateur peut également écouter le signal sonore de la détection et appeler à l'écran un graphique chronologique des données brutes. Un curseur peut être utilisé pour mesurer le temps et les fréquences de l'image de détection. Ce système a été utilisé avec succès pour traiter 30 minutes de données de bouées acoustiques contenant des vocalisations de baleines noires de l'Atlantique Nord.

Portée

Il y a encore beaucoup de chemin à faire à l'égard de la classification automatique et de la disposition de l'interface graphique (GUI), mais le prototype a montré que des détections peuvent être effectuées et classifiées au moyen d'un système de ce genre.

Recherches futures

Les essais initiaux du système sont très encourageants. Toutefois, il faut des essais supplémentaires au moyen de données « bruyants ». En outre, l'ajout d'algorithmes de classification et la mise en œuvre de détecteurs analogiques de « clics » sont les étapes logiques suivantes.

Glessing, B. et J. Hood. 2005. Marine Mammal Detection Final Report (détection de mammifères marins - rapport final). RDDC Atlantique CR 2005-271. R & D pour la défense Canada – Atlantique.

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1. Introduction

This final report outlines the work done under Noise Monitoring Software Regional Individual Standing Offer (RISO) No. W7707-032293/001/HAL, Call-up Requisition No. W7707-04-2801. This work was performed for Defence R&D Canada (DRDC) - Atlantic under the direction of the Scientific Authority (SA), Jim Theriault, from approximately February 2005 to September 2005. Some aspects of the work in Call-up Requisition No. W7707-04-2767 under the direction of the SA, Prakash Deonarine, is also discussed, with that work used as a basis for this call-up.

1.1 Overview

DRDC Atlantic is required to produce a prototype system that will provide detection and classification of whales and other marine mammals. The resulting system will be used to support environmental mitigation measures prior to, and during, active sonar trials and exercises. This call-up was generated to develop the prototype that would meet this requirement.

The objective of the previous call-up was to provide enhancements to the existing Sentinel module in the signal processing packages (SPPACS) suite and the enhancement necessary to support assessment, refinement and rationalization of the detection algorithm for marine mammals. Additionally, this call-up was concerned with developing core signal processing software that could be later integrated into a whale detection and classification system.

The objective of the second call-up was to provide feature extraction processing and GUI for the operator. The feature extraction capability could include image de-noise, image segmentation and feature extraction. The GUI would display the gram image output, detection details (i.e., channel, band, etc.) and provide data assessment to support manual classification.

Several papers have been produced detailing whale detection and classification algorithms and the performance of those algorithms given real data. Analysis of those algorithms against existing SONLIB/SPLIB modules revealed that much of the software required to develop a whale detection and classification system already existed. The two modules of interest are the Sentinel detector and the passive processing module. Under the direction of the SA, MacDonald Dettwiler and Associates Ltd. (MDA) used the Sentinel and omni passive processing modules to develop a generic transient detection and classification framework from which specific whale detection and classification algorithms could be implemented.

A working application was delivered at the end of the call-up. It allows a user to configure and run detection processing, with live updates provided in the window, or to post-analyze data from a previous detection run. Once selected, an image of the detection and the corresponding detection log entries are presented to the user. The user can also listen to the detection and bring up a time series plot of the raw data. A cursor can be used to measure times and frequencies on the detection image.

The new application was used to process 30 minutes by 49 channels of Right whale data collected using sonobuoys. This data was collected by Francine Desharnais in the Bay of Fundy during the summer of 1999. This data included dead channels, considerable RF interference and a digital data channel. Fifty-seven valid detections were made while the sixteen false alarms that did occur were easily classified and rejected. No analysis of missed contact was conducted. After a quick look at

the data, it took an acoustic operator, Joe Hood, less than a second to distinguish a valid call from a false alarm as he scrolled through the results. Aural listening quickly helped to distinguish valid versus invalid contacts. There is still room for improvement in the automatic classification and GUI layout, but as a prototype it demonstrates that good detections can be made and classified using a system such as this.

In reality the delivered application is a transient detection system and could be used for other purposes. The Acoustic Data Analysis Center (ADAC) has already shown an interest in using it for detecting and viewing submarine transients.

This report is broken into five main sections. The remainder of this section provides background on the software used during the call-up. Section 2 provides an overview of the call-up's software development requirements and work performed to meet those requirements. Section 3 documents the data analysis, results and recommendations. Section 4 details software configuration management processes and the versions used for this call-up. Section 5 provides a summary of current software issues.

1.2 Background

The data processing and analysis work was performed using two software suites: Software Tools for Analysis and Research (STAR) and SPPACS. An overview of the two software suites is provided in the following subsections.

The STAR and SPPACS suites are configuration controlled using the concurrent versioning system (CVS). Issue and enhancement idea tracking is affected using the Bugzilla issue tracking software. CVS is a repository that allows developers to check-in revisions to software and documentation where they are archived in a common database. The tool allows all previous versions of the software to be maintained and aids resolution of new issues, while ensuring that current builds of the software are readily accessible to users and developers alike. Bugzilla is a web accessible database that offers both user and developer input to issues, priorities and solutions. It provides coherent tracking and recording of an issue over its entire lifecycle.

STAR and SPPACS components are documented in a combination of formats, each with their own purpose. Microsoft Word documents are maintained, which describe functionality and algorithms of components. These are primarily intended for the end user. Enterprise Architect (EA) files are maintained, which document software design, interaction and dependencies. EA design information is intended primarily for developers. Hypertext Markup Language (HTML) library documentation is being developed that provides automatic extraction of the routine's Application Program Interface (API), purpose and description. This documentation is maintained to assist developers in familiarizing themselves with the existing libraries and components, and is intended to support and encourage software reuse. Some users may also wish to refer to this information for use in their own custom applications. SPPACS also provides HTML and man page user documentation for each module.

The most current status of the SPPACS and STAR suites can be found at <https://star.iotek.ns.ca>. Users are also encouraged to refer to the electronic documentation provided with the software distribution for up-to-date information.

1.2.1 STAR

The STAR suite was developed to support general research and analysis objectives at DRDC Atlantic. The primary objectives of the STAR suite are:

- Provide scientific grade analysis tools that allow for efficient, detailed quantitative and qualitative analysis of a data set.
- Support synergy between DRDC groups and the Department of National Defence (DND) by providing a common software base for analysis. This synergy encourages inter-group communication and simplifies user training, analysis process development, documentation and data portability.
- Support cost and analysis efficiency by providing software reuse and common tools and data formats. Examples of efficiency would be using the output of analysis from one group to feed the inputs of another, or using common software components to lower development cost of several custom analysis tools.

All STAR components are currently implemented using Interactive Data Language (IDL), though the design is not restricted to IDL. The name STAR reflects the generic nature of the software. Applications in the STAR suite are built using a combination of reusable and custom components that meet the requirements of each application. The layered design and common components allow for rapid and logical development of new capabilities. Though currently focused on sonar data processing and analysis, the tools are capable of expanding to meet other analysis and research requirements.

1.2.2 SPPACS

SPPACS is a group of software programs that are based on the C programming language and is implemented on Linux-based personal computers (PC). Each program provides a specific processing function and a series of programs can be chained together to create a custom-processing stream using the command line or scripts. The output from SPPACS is stored in DREA formatted data files. SPPACS has slowly evolved to its present day state due to the efforts of several MDA personnel over the last 4 years.

SPPACS has been used to perform a number of mid-trial and post-trial processing functions, such as the post-trial study of multistatic trial data and the mid-trial analysis of the Q265 sonobuoy test trial. SPPACS only performs data manipulation and does not provide an interface to examine the results. The processed data output is often imported into other applications that enable data display and are used to perform the detailed analysis of the results. One example of such an application is the STAR suite.

The SPPACS software suite consists of two types of software. One type is runtime executables that can be used to process DRDC Atlantic data files in a number of ways, including data management and signal processing. Each program performs a specific function and the programs are designed so that they can be used in conjunction to perform more complex processing tasks. The software has proven to be very useful in simplifying data management and sonar processing tasks by providing a set of tools from which to build the necessary processing streams. These streams can be run from the command line or assembled into scripts to perform batch-processing tasks allowing for large amounts of data to be automatically processed. The second form of the

software is a group of library functions that can be used by other programs to efficiently perform standard tasks. These library functions are extensively used by the runtime software, but are also used for other applications. There are now three types of libraries. The first are utility routines for performing tasks, such as header manipulation and command line parsing. The second are signal processing modules termed SPLIB. These are low-level modules, each performing a low level signal-processing task. A new SPPACS module typically consists of one or more SPLIB modules linked together with an SPPACS user interface. The final library type is a sonar processing module termed SONLIB. These are more complex modules that combine several SPLIB modules to create a complex sonar module, such as passive processing. Separating the SPLIB and SONLIB modules from SPPACS generated more generically reusable software. SPLIB and SONLIB are independent of the data header format, timestamping method, etc. and are suitable for integration in real-time processing systems.

SPPACS is also supported by a set of signal processing libraries known as the Fastest Fourier Transform in the West (FFTW). These free, open-source libraries provide optimized signal processing functions helping to ensure that the SPPACS software runs as efficiently as possible, while providing a significant reduction in coding effort.

2. Work Overview

This section presents an overview of the tasked and completed work. The development requirements for this call-up are listed in Table 1 and Table 2, while the remainder of this section indicates how each requirement was met. The work completed under this call-up was included in STAR Release 4.8.0.

This section is not meant to provide all technical details. A detailed description of the algorithms and technical aspects related to the work performed under this contract can be found in HTML documentation, included with the source code. It will be found in the acoustics documentation directory, which is generally /usr/local/atools/acoustics/doc.

Several accomplishments described in this contract rely on work conducted under other contracts. By sharing a common code base, several contracts were able to reduce the amount of effort required to meet their individual requirements and realize more overall benefit with the available funds.

As this contract was restricted by a limitation of expenditure and the contract objectives were ambitious, not all requirements were completely implemented, though substantial progress was made. MDA worked with the SA to ensure that the call-up deliverables were satisfactory allowing trade-offs to be made, as required. The following requirements were not, or only partially addressed:

- Transient Feature Extraction – This section of processing stream was not implemented, though a binary quantized gram was presented to the operator. A cursor could then be used to perform manual feature analysis. An aural listening capability was also added to the GUI.
- Event Analysis – As feature extraction wasn't performed no detailed event information was available. Instead, a list of the detection log entries was provided in the GUI.

Table 1. Contract Requirements for Whale Detection and Classification Aids (Call-up 1)	
REQUIREMENT TITLE	ASSOCIATED REQUIREMENTS
Data Buffering and Recording	<ul style="list-style-type: none">• The contractor shall implement a circular buffer module that maintains a buffer of the most recent N records of data. N is defined on initialization. If a detection is made the most recent N records plus a user defined number of post-detection records shall be copied to a single output record of the output buffer for the detecting channel.• The contractor shall implement a wave file writer module that accepts all data in one input buffer record and writes it to a single channel wave file with an SA defined file-naming scheme.
Detection	<ul style="list-style-type: none">• The contractor shall generate a SONLIB module that integrates the modules shown in Figure 1 and exposes the SA defined parameters to the user.

Table 1. Contract Requirements for Whale Detection and Classification Aids (Call-up 1)	
REQUIREMENT TITLE	ASSOCIATED REQUIREMENTS
Transient Pre-processing	<ul style="list-style-type: none"> • The contractor shall develop a time-frequency normalizer module for SPLIB under SA direction. • The contractor shall implement a binary quantizer module. • The contractor shall implement a module that convolves an SA defined kernel over the acoustic 'image' produced by the binary quantizer.
Transient Feature Extraction	<ul style="list-style-type: none"> • The contractor shall integrate the image segmentation software provided by John Fawcett into an SPLIB module. • The contractor shall implement an SPLIB module that finds each segment in the image and outputs a list of features for that segment including: <ul style="list-style-type: none"> ➤ Start and End Frequency ➤ Sweep Frequency ➤ Min and Max Frequency ➤ Position of Min and Max Frequency ➤ Instantaneous bandwidth ➤ Duration ➤ Area Ratio ➤ Porosity ➤ Mean Center
SPPACS Whale Detection	<ul style="list-style-type: none"> • The contractor shall integrate the detection and feature extraction modules into an SPPACS application using SA defined parameter options and SA defined data output options. This module will be used for testing and analysis of the modules performance.

Table 2. Contract Requirements for Marine Mammal DC System Integration (Phase 2)	
REQUIREMENT TITLE	ASSOCIATED REQUIREMENTS
Module Integration	<ul style="list-style-type: none"> • The contractor shall integrate the detection and feature extraction modules into an SPPACS application that accepts data using the method described in Task 2. • The application shall: <ul style="list-style-type: none"> • Accept configuration information using the method agreed upon in Task 2. • Accept raw data using the method agreed upon in Task 2. • Output detection event Wave, Feature and Image files using the formats defined during Task 2.

Table 2. Contract Requirements for Marine Mammal DC System Integration (Phase 2)	
REQUIREMENT TITLE	ASSOCIATED REQUIREMENTS
Event Analysis	<ul style="list-style-type: none"> • The contractor shall create a STAR application that allows users to see a list of current detection events in a designated directory and analyze those events. • The application shall: <ul style="list-style-type: none"> • Present the user with a list of events. • Allow the user to view the Feature and Image data. • If feasible, play the Wave file. If not, then the Wave file name should be presented to the user for manual selection. • Allow the user to annotate the Feature file with a manual classification and notes.

2.1 Development Work

The following work was completed to address the requirements listed in Table 1 and Table 2. Figure 1 shows the component diagram for the transient detection system. The system consists of a processing stream created from new and existing SPLIB/SONLIB modules, an SPPACS command line utility and a QT-based GUI. A considerable amount of reuse was realized under this call-up (approximately 50-60%). The modules shaded in green were created in the call-ups. The modules shaded in blue were enhancements. In this case, many of the enhancements resulted from the creation of a lightweight C++ wrapper for an existing module (see section 2.1.1.1). The modules shaded in yellow were written under previous call-ups. The modules shaded red were not completed.

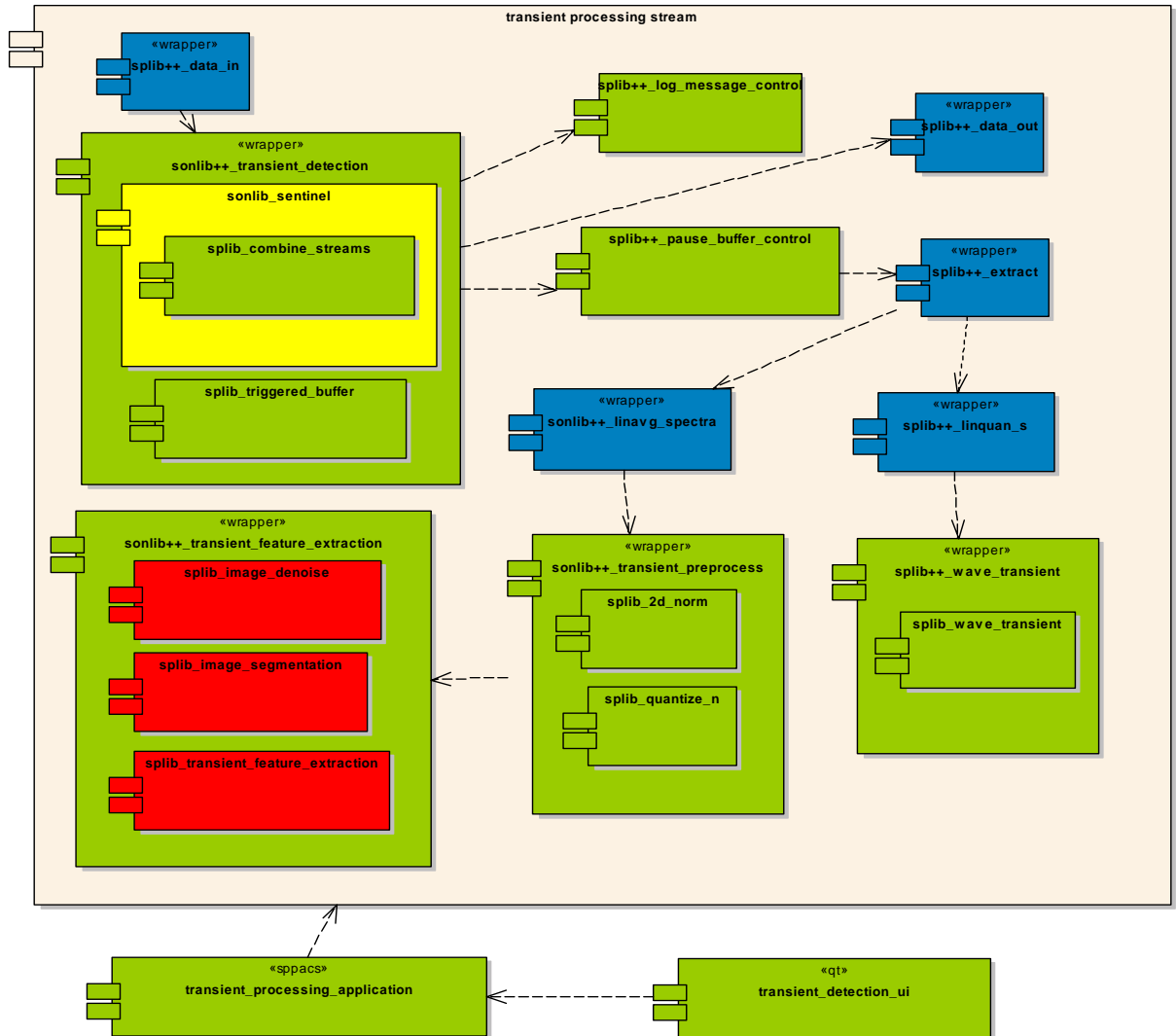


Figure 1. Component Diagram –Transient Processing Stream

2.1.1 Processing Modules

This section describes the processing modules that were created to address the call-up requirements.

2.1.1.1 SPLIB++/SONLIB++ C++ Signal Processing Layer

A C++ based control layer was utilized to support the processing stream. The SONLIB++/SPLIB++ framework provides a flexible/feature rich C++ layer. The framework can be used to create lightweight wrappers around existing SPLIB/SONLIB (C based) processing modules. Additionally, complex control modules can be created and used to monitor and manage the processing stream. Development of this layer was shared with the Rapid Deployable Systems Technology Demonstration (RDS TD) project.

The following wrappers were created from existing SPLIB modules:

- splib_extract
- splib_data_in
- splib_data_out
- splib_lin_quan_s
- splib_wave_transient

The following wrappers were created from existing SONLIB modules:

- sonlib_transient_detection
- sonlib_linavg_spectra
- sonlib_transient_preprocess

The following modules were written using the framework:

- pause_buffer_control
- log_messages_control

2.1.1.2 Triggered Buffer

A triggered buffer SPLIB module was created to provide a block of data around an event. It does this by cycling raw data through a circular buffer. The buffer is sized to ensure that a full data block is available. The module monitors the Sentinel module for new detections that trigger the output. When a new detection occurs the module waits for the defined number of post-event records to fill the internal buffer, and then copies the contents of the internal buffer to its output buffer. Each chunk of data contains a number of records before and after the detection, based on user settings.

The module was implemented to support the data buffering and recording requirement.

2.1.1.3 Pause Buffer Control

The application needed the ability to process a detection, reconfigure processing and then process data from the next detection. To do this, an SPLIB++ module (see section 2.1.1.1), called *pause buffer control*, was created to control data flowing through the processing stream. This module was placed after the transient detection module. The module allows an operator-specified number of records, in this case the size of a data block from the triggered buffer, to flow downstream and then discontinues reading/writing data until the downstream modules have completed processing. When the downstream modules have completed, the pause buffer control module sends a discontinuity event. This allows the downstream modules to cleanup and re-initialize before it makes the next set of data available.

This module was implemented to support the data-buffering requirement.

2.1.1.4 Wave Output

The application required that detections be captured and placed into a single channel wave file. A SPLIB module called `splib_wave_transient` was created to output the raw detection data to a single channel wave file. The following file naming convention was used:

`transient_detection_YYYY_MMDD_HHMMSS_ID_detect_id_X_receiver_Z.wav`

Where:

- YYYY_MMDD_HHMMSS is the time that processing was started.
- ID is a serial number used to uniquely identify a file grouping. The transient detector does not make use of this field when generating output files.
- The X following `detect_id` is an integer that indicates the detection number.
- The Z following `receiver` is the receiver ID that the detection occurred on.

Note: Both X and Z are zero indexed (i.e. `receiver_0`).

An SPLIB++ module called `wave_transient` was created to wrap the SPLIB module.

These modules were implemented to support the data buffering and recording requirement.

2.1.1.5 Log Output

The application required that detection information be written into an American Standard Code for Information Interchange (ASCII) file for logging. An SPLIB++ module called `log_messages_control` was created to read and write log messages from the transient detection module. Each detection message received from the transient detection module is converted into a STAR style log entry (See `STAR_analysis_technical_manual.doc`) and written to a log file. If a log file already exists the module will append new detection messages to the end of the log.

2.1.1.6 Combine Records

The application required a single stream that would indicate how far the current data was either below or above the detection threshold. The long term plan is to feed this stream to a graphical or analogue level meter. To support this, an SPLIB combine records module was created. It outputs a single peak energy value relative to threshold across all channels. The output data is a single float value per record.

This module was implemented to support the detection requirement.

2.1.1.7 Transient Detection

A transient detection SONLIB module (`sonlib_transient_detection`) was written to control the Sentinel processing SONLIB module, the triggered buffer SPLIB module, and the combine

records SPLIB module. This makes all the outputs from these modules available to higher layers of code.

A SONLIB++ module called `transient_detection` was created to wrap the SONLIB module. This module was implemented to support the detection requirement.

2.1.1.8 Time Frequency Normalizer

It is desirable to enhance signals prior to feature extraction, which is often done using a normalizer. In this case, it was desirable to enhance transient signals while not affecting longer lasting narrow bandwidth signals. This type of normalization was implemented using a time-frequency normalizer SPLIB module (`splib_2d_norm`). First, frequency based averaging was conducted using a median average. Then this average was damped in time using an exponential averager. Finally the overall average from each scan was used to normalize that scan.

The normalizer was included in the transient pre-processing module to support the transient pre-processing requirement.

2.1.1.9 N Level Quantizer

A simple binary version of the time-frequency data is needed for feature extraction and also creates a simple black and white GRAM showing where significant energy is present. An N level quantizer SPLIB module (`splib_quantize_n`) was written that supports from 1 to 255 levels of quantization. For this implementation N was set to 2, making it a binary quantizer.

This module was written to support the transient pre-processing requirement.

2.1.1.10 Transient Pre-processing SONLIB/SONLIB++

A transient preprocess SONLIB module was written to control the `splib_2d_norm` and `splib_quantize_n` modules. A SONLIB++ wrapper was created to allow the transient pre-processing SONLIB module to be incorporated into the processing stream.

This module was written to support the transient pre-processing requirement.

2.1.2 Interfaces

This section describes the SPPACS command line utility and the QT-based user interface (UI).

2.1.2.1 Target File

The processing stream is configured primarily through a target file. The target parser is used to read these files and format the contents into a form that the rest of the detection software can understand. For an example of a target file with comments, please refer to the `<distribution>/src/stealth/target_files/template.tgt` file within the source distribution. The target file configuration file format and associated parsing software was reused from the Sentinel stealth call-up and supports the module integration (configuration information) requirement.

An example target file follows:

```
# target = targetname
target=right_whale

# spectra parameters
nfft=1024 # FFT size to use
overlap=0.5 # percent overlap for FFT (0.0 to 1.0)
n_averages=1 # number of FFTs to average for each output
reference_gain=0.7 # value at which to switch between slow_background
# and fast_background time constant. When
# signal_level * reference_gain < background_level
# low_bg_alpha is used.
# Otherwise high_bg_alpha is used.
wait_n_records=5 # number of records (outputs) to wait before allowing
# detections
# choose from median or exponential signal estimation type
sig_estimator=exponential

# band=ID TYPE PARM fstart fend low_bg_alpha high_bg_alpha sig_alpha winsz thr
# band - fixed name to describe the following line
# ID - freeform text to describe the band (no whitespace allowed)
# TYPE - S (signal), N (noise) or I (independant band)
# PARM - if signal: PARM is the frequency normalized signal threshold
# - if noise: PARM is the text identifier of the associated signal band
# - if independant: PARM is not used, but must be present for parser to work
# fstart - band start frequency
# fend - band end frequency
# low_bg_alpha - low background time constant (0.0 - 1.0)
# high_bg_alpha - high background estimation time constant (0.0 - 1.0)
# sig_alpha - fast background time constant (0.0 - 1.0)
# winsz - median normalizer window size [records]
# thr - time normalized threshold level at which the Sentinel will trigger for all bands, but
# noise bands will never cause a detection and signal bands must also exceed the
# PARM threshold to trigger.
# NOTE: for alpha parameters 1.0 means never change the level from the start
# and values close to 1.0 cause it to change very slowly. 0.0 means
# always use the current level and values close to zero will change
# the level very quickly.
# Triggering of a signal or associated noise band will cause the narrowband test to
# occur.)
band=right_whale1 S 4.0 115.0 170.0 0.99 0.9 0.5 10 2.0
band=noise_right1_1 N right_whale1 40.0 100.0 0.99 0.9 0.5 10 3.0
band=noise_right1_2 N right_whale1 180.0 300.0 0.99 0.9 0.5 10 3.0

band=right_whale2 S 5.0 1300.0 1500.0 0.99 0.9 0.5 10 2.0
band=noise_right2_1 N right_whale2 1200.0 1300.0 0.99 0.9 0.5 10 3.0
band=noise_right2_2 N right_whale2 1500.0 1600.0 0.99 0.9 0.5 10 3.0

# band=shotgun I NA 50.0 3000.0 0.99 0.9 0.5 10 5.0
# band=shotgun I NA 1000.0 3000.0 0.99 0.9 0.5 10 3.0
#band=shotgun I NA 500.0 1500.0 0.99 0.9 0.5 10 4.0

transient_alpha=0.90
transient_window_size=50
breakpoints=8.0
```


2.1.2.2 SPPACS Whale Detection

An SPPACS utility was created to allow the transient processing stream to be executed through a command line interface. This supported testing and performance evaluation during the development effort. In addition, it allows the processing stream to be used in scripts for batch processing. This utility was created to address the SPPACS whale detection requirement.

The options available for the utility are as follows:

sp_transient_processing: [OPTIONS] < INPUT

-T [--target-file] arg	: target definition file
-d [--dat32-header]	: flag for DRDC header type.
-c [--detect-chunk-size] arg (=10)	: detection chunk size.
-p [--past-records] arg (=5)	: number of records saved before detection event.
--multi-time-const	
-i [--background-initial-values] arg	: initial values to initialize the background exp_average
-f [--log_file] arg (=transient_detection_log.txt)	: transient message log file
-a [--data-file] arg (=<stdin>)	: the data file
-m [--algorithm] arg (=0)	: algorithm to use for combine_records.
--help	: produce help message
--version	: produce version message

2.1.2.3 QT GUI

GUI was created to allow an operator to use the transient processing stream. Figure 2 shows the transient detection window. It consists of a detection list, feature list, wave output button group and image view. The detection list displays the detections found in an output directory. The image view displays a black and white image of a detection event. The feature list shows a listing of detection messages associated with a detection event. The wave control allows the operator to play, stop or view the raw detection event. This application was created to address the event analysis requirement.

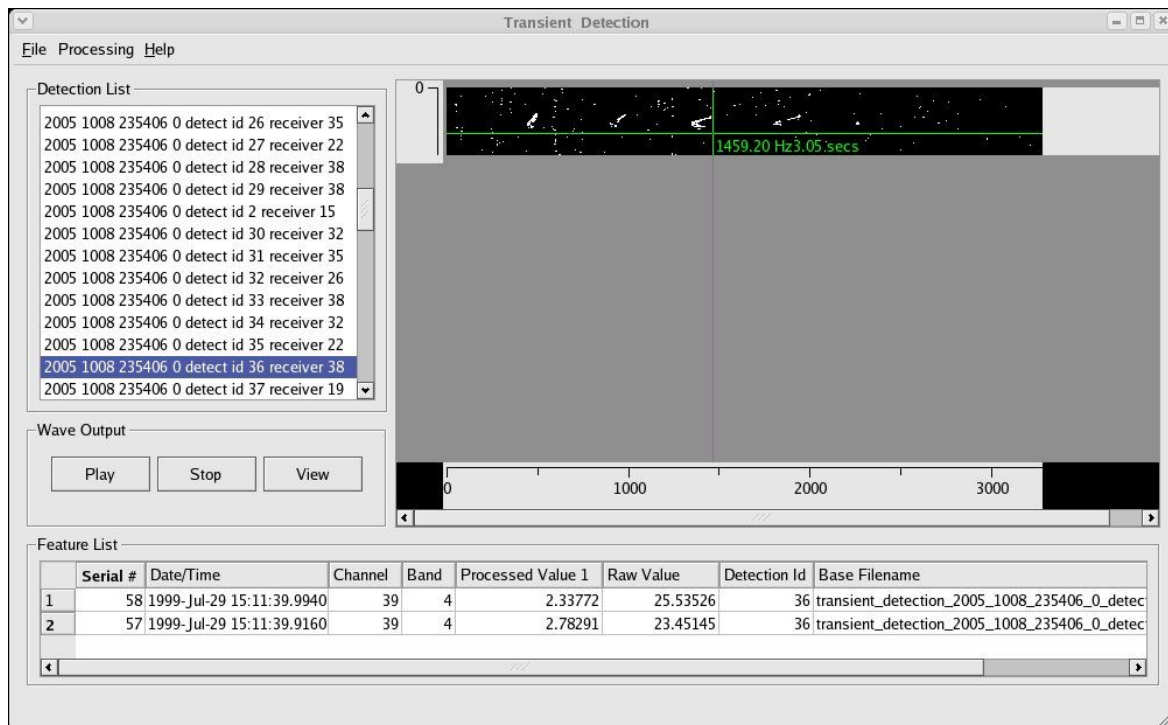


Figure 2. Transient Detection Application showing right_whale2 Detection

Input Settings: The input settings dialog is shown in Figure 3. The operator can change the type of input by selecting one of the tabs. Currently, only the file-based input is supported. It allows the operator to select an input file for processing and the type of file. Currently, the system supports DRDC DAT and DAT32 data files. Support for WAVE and Sound Card input can be quickly added, as modules exist to support these formats. To open the input settings dialog select Processing->Input Settings... from the menu bar.

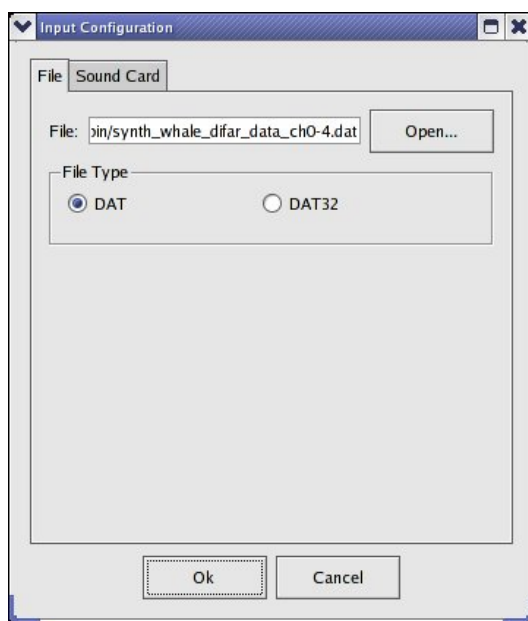


Figure 3. Input Settings Dialog

Processing Settings: The processing settings dialog is shown in Figure 4. It allows the operator to change the detect chunk size, past records, target file and output directory. Detect chunk size allows the operator to adjust the number of blocks around a detection event. Past records allows the operator to adjust the number of blocks that are captured before the detection event. (NOTE: The block size is the number of records in each Fast Fourier Transform (FFT) step size. This input should be converted to use seconds.) The target file is a configuration file used to define targets of interest (see section 2.1.2.1). The output directory is the directory that the processing stream will write all output files to. The output files include a detection log, wave files, power spectral files containing black and white images of each detection in a GRAM format and an energy time indicator (ETI) file containing raw band energy in a DREA .pwr format. In this case each bin is an ETI band. To open the dialog select Processing->Processing Settings... from the menu bar.

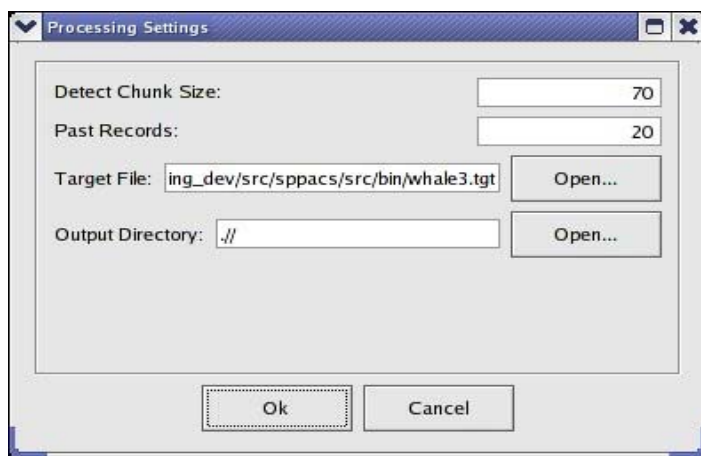


Figure 4. Processing Settings Dialog

Processing: The operator can start processing by selecting Processing->Start. This will execute the SPPACS utility `sp_transient_processing` using the settings from the input and processing settings dialogs. The output from `sp_transient_processing` is written to the output directory. The operator can stop processing by selecting Processing->Stop.

Detection List: The detection list will update with events as they are written to the output directory. The operator can view the data for a detection event by selecting the desired entry in the detection list. This will cause the image view to load the associated power spectral image and the feature list to display the detection messages associated with the detection event.

Image View: The image view displays the power spectral output for a detection event. The operator can scroll horizontally through the frequency range and vertically through the time range of the data. Clicking on the image will produce a crosshair cursor with frequency and time annotation.

Wave Output: The wave file containing the raw data for the select detection event can be viewed by selecting View in the Wave Output button group. This will open a plot of the wave file in a modal dialog (as shown in Figure 5). The operator can zoom into a particular section of the data by left-clicking and dragging the cursor to highlight the desired area. Right-clicking on the view area will cause the view area to display the entire data set.

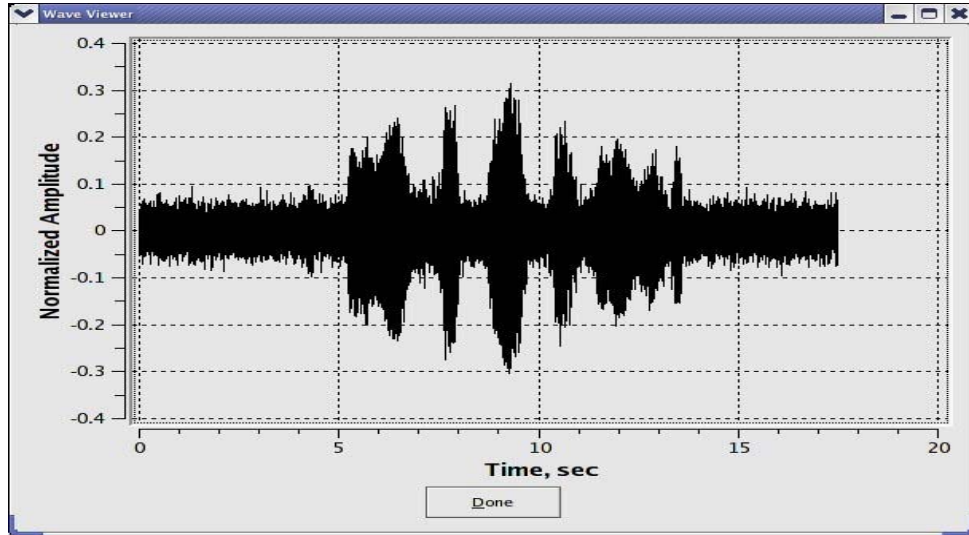


Figure 5. Wave View Dialog

3. Data Processing and Analysis

One of the tasks in this call-up was to process real data through the detection system to tune and assess performance. The SA had provided a number of CDs and DVDs with marine mammal calls on them for analysis, but this data was found to have too high of a contact density to be useful. Instead, the Project Engineer (PE) and SA agreed to use 30 minutes by 49 channels of Right whale data collected using sonobuoys. This data was collected by Francine Desharnais in the Bay of Fundy during the summer of 1999.

Before processing, some of the data was observed in the OPD application to assess the signature of some whale calls. Two dominant whale calls were found. One was a low moan around 150 Hz, while the other was a higher pitched song around 1400 Hz. These were characterized as right_whale1 and right_whale2 respectively in the target file shown in section 2.1.2.1. Shotgun events also occurred and successful detection events were made, but the false alarm rate was also quite high due to the lack of contrast between the shotgun event and many other transients. Further analysis may have provided a better characterization.

Once the whale calls were characterized the target file was used to process two 15-minute data files. The data files were created from digitized Analogue Tape Recorder (ATR) tapes in IMPACT format. Each file contained 49 channels, though many of the channels contained only noise and one channel contained digital data. The valid data channels consisted of single channel omni-directional buoy data and DIFAR data in three channel groups. The directional channels were processed the same as omni-directional channels to get some dipole gain for better detections. If the processing was for more than initial testing, proper beamforming could have been conducted.

The following summarizes the detections produced:

- 51 valid right_whale1 calls
- 6 valid right_whale2 calls
- 6 false right_whale2 calls from radio conversations
- 5 false right_whale2 calls from radio chirps – There was a short burst signal sent on processing channel 11 a number of times that exactly matched the band of the right whale2 call.
- 5 potentially false right_whale2 calls – These were waterborne transients that didn't have the aural characteristics of a song and were not shotgun calls. They were likely biologic, but the analyst couldn't confirm that they were from right whales.

The prototype GUI proved to be very useful in classifying contact. After a quick look through the data, it took an acoustic operator, Joe Hood, less than a second to recognize a valid call from a false alarm as he scrolled through the results. The initial look involved examining the black and white gram and listening to each type of intercept. As expected, aural classification was very useful and the gram provided for rapid image recognition. The gram also showed a fair variety in the whale call characteristics including duration, frequency sweep and harmonics seen. The time-series plot of data wasn't found to be very useful except that RF interference was obvious due to clipping.

The OPD application could have been used to search for missed contact, but this wasn't done due to effort limitations on the call-up. This will likely be done as part of another analysis call-up related to marine mammal localization.

There is still room for improvement in the automatic classification and GUI layout but, as a prototype, it demonstrates that good detections can be made and classified using a system such as this. The following subsection describes suggestions for improvement.

3.1 Suggestions for Improvement

As often happens during call-ups of this nature, not all ideas are exhausted during the call-up and new ideas are generated. This section documents some of those ideas as consideration for future work. It is hoped that more suggestions are generated by DRDC and ADAC as they use the application. Suggestions can be logged on the STAR portal at <https://star.iotek.ns.ca> or sent to Joe Hood at MDA (jhood@mdacorporation.com).

3.1.1 Reject / Accept Button

A reject/accept button should be added to the GUI. Once rejected or accepted, a detection could be placed on a different list to show what hasn't been analyzed. Further to this, freeform text annotation could be added to the /logs. This would allow the user to log notes with the detections.

3.1.2 Detection Summary

Currently, the raw detection logs are shown in the GUI. This should be changed to show a summary detection including total detection time, detection min / max level, etc. The detection log should also log the text name of the band being detected and not the band number.

3.1.3 Feature Extraction

Feature extraction wasn't implemented due to time constraints. Though the GRAM display enabled rapid image recognition for an operator, digital feature information will be required for more automated analysis and false alarm rejection. The first step in this is feature extraction, as planned.

The computer-aided detection/computer-aided classification (CAD/CAC) functionality used in the Sonar Image Processing System (SIPS) should be able to provide a number of reusable components to aid in feature extraction and classification.

Once features are extracted they could be automatically shown as each event is analyzed.

3.1.4 Zoom

It may be useful to zoom on the gram display to get a better view of one portion of the GRAM. Also, because the transient capture is often very short, it may be useful to show the default image in a zoomed mode.

3.1.5 Chunk Size Units

The UI should be changed to let the user define the chunk size in seconds and not the number of FFT blocks.

3.1.6 Live Data

More variations on the data in module should be added as options. This should include soundcard analogue-to-digital (A/D) output, WAVE files and other data capture hardware. This would enable a live trial at sea, which should prove very useful in generating further feedback on the design and algorithms.

3.1.7 Remote Sensing / Operational Use

The application was built so that it could be installed in systems like the Stealth buoy. This variant should also be trialed for remote monitoring of an area. The library modules could also be integrated into systems like the Integrated Multistatic Passive/Active Concept Testbed (IMPACT) for use during trials.

4. Maintain Configuration Management

STAR and SPPACS are maintained using subversion. The most recent release version is maintained and bug fixes are applied to that version, as required, ensuring that a stable release is always available. Simultaneously, software enhancements are applied to the development version and bug fixes are merged with this version. Once a call-up nears completion, or a release of the software is otherwise required, a new release version is branched off of the development stream for final integration, release testing and delivery.

STAR (includes SPPACS) release 4.8.0 (tag `star_release_4_8_0`) was created under this contract to serve as a baseline while the analysis work was being conducted. This allows development to continue on the trunk of the distribution. The trunk usually contains newly implemented software, which may not be stable enough to allow for operational use.

5. Track Software Issues

Defect tracking systems allow users to effectively keep track of outstanding bugs in their product. STAR and SPPACS issue tracking is performed using a web accessible tool called Bugzilla. This tool can be accessed using a secure web interface at <https://star.iotek.ns.ca>. Once the appropriate security procedures, detailed on the web page, have been followed, users and developers can use this site to add, view or modify issues related to the software packages.

A breakdown of the current issues for the STAR and SPPACS distributions are shown in Table 3. The total number of unresolved issues is shown in the NEW/ASSIGNED/ REOPENED column. The total number of opened issues is broken into two classes of severity. Issues classified as BLOCKER/CRITICAL/MAJOR are issues that should be addressed in the short term. Blockers are always addressed immediately to ensure that the user community can continue with their work. Issues classified as NORMAL/MINOR/TRIVIAL are issues that can be dealt with in the long term.

None of the issues described below affect this call-up.

Table 3. Distribution Issue Summary (01/11/2005)

PRODUCT	NEW/ASSIGNED/ REOPENED (TOTAL)	BLOCKER/CRITICAL/ MAJOR	NORMAL/MINOR/ TRIVIAL
SPPACS	39	1	38
STAR	60	4	56

The following gives a more detailed description of the SPPACS BLOCKER/ CRITICAL/MAJOR column:

- Issue # 284 (major) **fails DAT32 byteswap case**. The utility is attempting to read the extra gains using the original header, which may be in a different byte-order than the platform.

The following list gives a more detailed description of the STAR BLOCKER/ CRITICAL/MAJOR column:

- Issue # 193 (critical) **tacplot does not cleanup before exiting**. The workaround for this issue is to run `heap_gc` after the analysis window has closed.
- Issue # 107 (major) **problems capturing close button**. A solution exists for this, but has only been incorporated into the tactical plot. The exit button provides application termination capability.
- Issue # 295 (major) **capture screen doesn't work correctly**. The Capture Screen button does a screen capture on the analysis window and not the tactical plot. Taking a screen capture immediately after opening the window can solve this problem. A fix has been implemented and will be released with the next version.

- Issue # 329 (major) **overlays need to be optimized.** The tactical plot is too slow (on Bender). To load on Bender (dual P4- 1 GHz), it takes approximately 20 seconds the first time and 15 to 20 seconds thereafter. If you don't require AOP overlays on the tactical plot, disable them on the tactical plot settings dialog.

6. References

1. The Software Tools for Analysis and Research Data Analysis and Technical Manual – Revision 1,
(/usr/local/atools/acoustics/src/analysis_tools/documents/STAR_analysis_technical_manual.doc) STAR Release 4.8.0

List of symbols/abbreviations/acronyms/initialisms

A/D	Analogue-to-Digital
ADAC	Acoustic Data Analysis Center
API	Application Program Interface
ASCII	American Standard Code for Information Interchange
ATR	Analogue Tape Recorder
CAD/CAC	Computer-Aided Detection/Computer-Aided Classification
CD	Compact Disc
CVS	Concurrent Versioning System
DND	Department of National Defence
DRDC	Defence Research & Development Canada
DREA	Defence Research Establishment Atlantic
DRP	Document Review Panel
DVD	Digital Versatile Disc
EA	Enterprise Architect
ETI	Energy Time Indicator
FFT	Fast Fourier Transform
FFTW	Fastest Fourier Transform in the West
GUI	Graphical User Interface
HTML	Hypertext Markup Language
ID	Identification

IDL	Interactive Data Language
IMPACT	Integrated Multistatic Passive/Active Concept Testbed
MDA	MacDonald Dettwiler and Associates Ltd.
OPD	Omni Passive Display
PC	Personal Computer
PE	Project Engineer
RDS TD	Rapid Deployable Systems Technology Demonstrator
RF	Radio Frequency
RISO	Regional Individual Standing Offer
SA	Scientific Authority
SIPS	Sonar Image Processing System
SONLIB	Sonar Library
SPLIB	Signal Processing library
SPPACS	Signal Processing Package
STAR	Software Tools for Analysis and Research
UI	User Interface

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(U) This report documents the work done to prototype a marine mammal detection system. The resulting system will support environmental mitigation measures prior to, and during, active sonar trials and exercises. A working application was delivered at the end of the call-up that allows a user to configure and run detection processing, with live updates provided in the window, or to post-analyze data from a previous detection run. Once selected, an image of the detection and the corresponding detection log entries are presented to the user. The user can also listen to the detection and bring up a time series plot of the raw data. A cursor can be used to measure times and frequencies on the detection image. This system was used to process 30 minutes of Right whale data collected using sonobuoys. This data was collected by Francine Desharnais in the Bay of Fundy during the summer of 1999. This data included dead channels, considerable radio frequency (RF) interference and a digital data channel. Fifty-seven valid detections were made while the sixteen false alarms that did occur were easily classified and rejected. No analysis of missed contact was made. After a quick look at the data, it took an acoustic operator less than a second to recognize a valid call from a false alarm as he scrolled through the results. Aural listening quickly helped to confirm and adjust to valid vs. invalid contact differentiation. There is still considerable room for improvement in the automatic classification and graphical user interface (GUI) layout but, as a prototype, it demonstrates that good detections can be made and classified using a system such as this. The processing stream is based primarily on existing signal processing library (SPLIB) and sonar library (SONLIB) modules developed under previous call-ups. The GUI was based on existing QT-based widgets developed under the Omni Passive Display (OPD) call-up.

(U) Le présent rapport fait état des travaux effectués sur un système prototype de détection de mammifères marins. La version finale du système viendra appuyer les mesures de protection environnementale avant et pendant les essais et exercices faisant appel au sonar actif. À la fin de la commande directe, l'entrepreneur a livré une application opérationnelle qui permet à l'utilisateur de configurer et d'exécuter le traitement des données de détection, avec des mises à jour en temps réel, ou d'effectuer une analyse postérieure des données d'un essai de détection antérieur. Une fois sélectionnée, une image de la détection et les entrées correspondantes dans le journal de détection sont présentées à l'utilisateur. L'utilisateur peut également écouter le signal sonore de la détection et appeler à l'écran un graphique chronologique des données brutes. Un curseur peut être utilisé pour mesurer le temps et les fréquences de l'image de détection. Ce système a été utilisé pour traiter 30 minutes de données de détection de baleines noires collectées au moyen de bouées acoustiques. Desharnais a collecté cet ensemble de données dans la baie de Fundy au cours de l'été 1999. Cet ensemble de données comprenait des canaux inactifs, du brouillage radiofréquence (RF) considérable et un canal de données numériques. Cinquante-sept détections valides ont été effectuées, tandis que les seize fausses alertes qui se sont produites ont été faciles à classer et à rejeter. Aucune analyse de contacts manqués n'a été effectuée. Après un survol rapide des données, un opérateur de détecteurs acoustiques a mis moins d'une seconde à distinguer entre un contact valide et une fausse alerte pendant qu'il faisait défiler les résultats. L'ouïe a aidé à distinguer rapidement entre les contacts valides et non valides. Il y a encore beaucoup de chemin à faire à l'égard de la classification automatique et de la disposition de l'interface graphique (GUI), mais le prototype a montré que de bonnes détections peuvent être effectuées et classifiées au moyen d'un système de ce genre. Le flux de traitement est essentiellement fondé sur les modules existants de bibliothèque de traitement de signaux (SPLIB) et de bibliothèque sonar (SONLIB) développés dans le cadre de commandes directes antérieures. L'interface GUI était basée sur des objets fenêtres axés sur QuickTime développés dans le cadre de la commande directe visant l'affichage Omni passif (OPD).

14. KEYWORDS, DESCRIPTORS or IDENTIFIERS (Technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible keywords should be selected from a published thesaurus, e.g. Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus identified. If it is not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title.)

(U) Acoustic
Detection
Marine Mammal

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